REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave Blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	July 17, 1998	Interim Report - 6/1/97-5/31/98

4. TITLE AND SUBTITLE
"Turbulence in Two and Three Dimensions"

5. FUNDING NUMBERS
N00014-98-1-0047

PR - 98PR00293-00

6. AUTHORS
Harry L. Swinney, Principal Investigator

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
The University of Texas at Austin
Office of Sponsored Projects
Austin, TX 78712

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
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10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

No limitations

13. ABSTRACT *(Maximum 200 words)*

Laboratory experiments on a zonal flow in a rotating annulus yielded insight into the phenomenon of blocking in the atmosphere (where the jet stream is deflected poleward by blocking anticyclones that persist for 10 days or longer). With two symmetric ridges on the bottom of the laboratory annulus, the resulting flows were nearly zonal at high forcing, blocked at low forcing, and intermittently switched between zonal and blocked flows at intermediate forcing. These observations provide new criteria by which topographic effects on low-frequency atmospheric flows can be distinguished from thermal effects.

A model of one-dimensional random walks was examined in which the probability distribution functions for forward and backward steps were both power laws but with different exponents. Relations were derived between the exponent for the variance of the displacement and the exponents for the probability distribution functions for forward and backward steps and for sticking events. The results for this model agree with observations of tracer particles in a multi-vortex flow in a laboratory rotating annulus.

Another study developed a genetic algorithm that produces neural feedback controllers for chaotic systems. The computer program to implement the algorithm is available on the World Wide Web at http://chaos.ph.utexas.edu/~weeks/dsane/

14. SUBJECT TERMS		15. NUMBER OF PAGES
Nonlinear dynamics	fluid flows	3
		16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

ANNUAL PERFORMANCE (TECHNICAL) REPORT

OFFICE OF NAVAL RESEARCH

Report Period: 6/1/97 - 5/31/98

PART I

PUBLICATIONS/PATENTS/PRESENTATIONS/HONORS REPORT

Contract/Grant Title:	"Turbulence in Two and Three Dimensions"
Principal Investigator:	Harry L. Swinney
Mailing Address:	University of Texas at Austin Center for Nonlinear Dynamics Austin, TX 78712
Phone Number:	512-471-4619
Fax Number:	512-471-1558
E-mail Address:	swinney@chaos.ph.utexas.edu
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a. Number of papers submitted to refereed journals, but not published: 1

b. Number of papers published in refereed journals: 4

[1] E. R. Weeks, Y. Tian, J. S. Urbach, K. Ide, H. L. Swinney, and M. Ghil, "Transitions between blocked and zonal flows in a rotating annulus with topography," Science **278**, 1598-1601 (1997).

[2] Eric R. Weeks and Harry L. Swinney, "Anomalous diffusion resulting from strongly asymmetric random walks," Physical Review E **57**, 4915-4920 (1998).

[3] E. R. Weeks and H. L. Swinney, "Random walks and Levy flights observed in fluid flows," Nonlinear Science Today (Jan. 1998)

[4] E. R. Weeks and J. M. Burgess, "Evolving artificial neural networks to control chaotic systems," Physical Review E **56**, 1531-1540 (1997).

c. Number of books or chapters submitted, but not yet published: 1

d. Number of books or chapters published: 1

e. Number of printed technical reports/non-refereed papers: 0

f. Number of patents filed: 0

g. Number of patents granted: 0

h. Number of invited presentations: 11

6/30/97	G.I. Taylor Symposium, Northwestern University, Chicago
9/12/97	Natural Sciences Foundation Advisory Council, UT-Austin
11/14/97	5th Chemical Congress of North America, Cancun
11/25/97	Physical Chemistry Seminar, U of California, Berkeley
2/3/98	Department of Physics Colloqium, U of Houston
3/20/98	Annual Spring Meeting, Texas Sections-AAPT/APS, U of Incarnate Word, San Antonio
3/26/98	Interdisciplinary Lecture Series, UT-Austin

4/14/98 Department of Physics Colloquium, Trinity U, San Antonio
4/29/98 Joe Ford Memorial Lecture, Georgia Tech, Atlanta
5/11/98 Workshop on Pattern Formation and Nonlocal Effects, U of Minnesota
5/13/98 Physics Department Colloquium, U of Minnesota

i. Number of submitted presentations: 6

j. Honors/Awards/Prizes for contract/grant employees: 1
Center for Nonlinear Dynamics ranked first in nonlinear dynamics programs by U. S. News & World Report (1998) (3rd year)

k. Total number of full-time equivalent graduate students and postdoctoral associates supported during this period, under this project number:
Graduate students: 1.5
Postdoctoral Associates: 1
Female Graduate Students: 0
Female Post-doctoral Associates: 0
Minority Graduate Students: 0
Minority Post-doctoral Associates: 0
Asian Graduate students: 0
Asian Post-doctoral Associates: 0

l. Other funding:

Department of Defense, Navy (AASERT)
"Turbulence in Two and Three Dimensions"
$95,000 (total)
8/1/96 - 5/31/99
Relationship to ONR grant: student training on this ONR project

Department of Energy
"Complex Spatiotemporal Patterns in Nonequilibrium Systems"
$158,000 (current year)
$1,171,829 (total)
9/1/97 - 8/31/02
Relationship to ONR grant: None (concerns granular and chemical media)

National Aeronautics and Space Administration
"Experiments and Theory on Instability in Surface-Tension-Driven Benard Convection (Marangoni Convection)"
$125,000 (current year)
$500,000 (total)
6/1/96 - 5/31/00
Relationship to ONR grant: Very little. An ONR-purchased infrared camera is used in convection studies.

National Science Foundation - International Programs
(Cooperative Program with FONDECYT, Chile)
"Pattern Formation in Vertically Oscillated Granular Materials"
$31,008 (U. S. Budget - total) This grant is for travel only.
1/15/95 - 12/31/98
Relationship to ONR grant: None

Robert A. Welch Foundation
"Resonant Pattern Formation in a Perturbed Belousov-Zhabotinsky Reaction"
$42,000 (current year)
$120,000 (total)
6/1/98 - 5/31/01
Relationship to ONR grant: None

Texas Advanced Research Program
"The Physics of Vibrated Granular Media"
$81,375 (total for three years)
1/1/95 - 8/31/98
Relationship to ONR grant: None

PART II

a. Program Objective: To understand basic mechanisms of instability and turbulence in rotating fluids in two and three dimensions.

b. Significant results during last year:

Laboratory experiments on a zonal flow in a rotating annulus yielded insight into the phenomenon of blocking in the atmosphere (where the jet stream is deflected poleward by blocking anticyclones that persist for 10 days or longer). With two symmetric ridges on the bottom of the laboratory annulus, the resulting flows were nearly zonal at high forcing, blocked at low forcing, and intermittently switched between zonal and blocked flows at intermediate forcing [1,2]. These observations provide new criteria by which topographic effects on low-frequency atmospheric flows can be distinguished from thermal effects.

A model of one-dimensional random walks was examined in which the probability distribution functions for forward and backward steps were both power laws but with different exponents [3]. Relations were derived between the exponent for the variance of the displacement and the exponents for the probability distribution functions for forward and backward steps and for sticking events. The results for this model agree with observations of tracer particles in a multi-vortex flow in a laboratory rotating annulus.

Another study developed a genetic algorithm that produces neural feedback controllers for chaotic systems [4]. The computer program to implement the algorithm is available on the World Wide Web at http://chaos.ph.utexas.edu/~weeks/dsane/

c. Summary of plans for next years work:

We will examine two-dimensional (2D) turbulence in a rapidly rotating annulus where the flow is constrained to be 2D by the Taylor-Proudman theorem. The velocity field will be determined by particle imaging velocimetry and the results will be compared with predictions for 2D turbulence. The transition from 2D to 3D flow will be produced by either reducing the rotation rate of the annulus or by increasing the strength of the forcing. The observed properties of the 2D to 3D transition will be compared with theory and numerical simulations.

d. Graduate students and post-doctoral currently working on the project:
Brendan Plapp, postdoctoral fellow
Charles Baroud, graduate student

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July 16, 1998

Office of Naval Research
Program Officer Michael F. Shlesinger ONR 331
Ballston Centre Tower One
800 North Quincy Street
Arlington, VA 22217-5660

Dear Michael,

Enclosed is my annual report and reprints of our papers from the current grant year. We are especially pleased with the results on atmospheric blocking phenomena (*Science* reprint is enclosed).

Reprints are also enclosed on our work on strongly asymmetric random walks, and on a neural network algorithm for controlling chaotic systems.

Let me know if you have any questions. With best wishes.

Sincerely,

Harry

Harry L. Swinney

HLS/df

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